



Developing Signal Processing Blocks for Software-defined Radios

by Gunjan Verma and Paul Yu

ARL-TR-5897

January 2012

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

Army Research Laboratory

Adelphi, MD 20783-1197

ARL-TR-5897

January 2012

Developing Signal Processing Blocks for Software-defined Radios

Gunjan Verma and Paul Yu
Computational and Information Sciences Directorate, ARL

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
<p>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p> <p>PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</p>					
1. REPORT DATE (DD-MM-YYYY) January 2012		2. REPORT TYPE Final		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE Developing Signal Processing Blocks for Software-defined Radios				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Gunjan Verma and Paul Yu				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory ATTN: RDRL-CIN-T 2800 Powder Mill Road Adelphi, MD 20783-1197				8. PERFORMING ORGANIZATION REPORT NUMBER ARL-TR-5897	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Software-defined radios (SDRs) provide researchers with a powerful and flexible wireless communications experimentation platform. GNU Radio is the most popular open-source software toolkit for deploying SDRs, and is frequently used with the Universal Software Radio Peripheral (USRP). After establishing a USRP testbed, the researcher will need to implement new signal processing algorithms or modify existing ones. This document describes this process, highlighting those details that have received minimal attention in the existing documentation.					
15. SUBJECT TERMS Software radios, CHU Radio, USRP Ubuntu					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 44	19a. NAME OF RESPONSIBLE PERSON Gunjan Verma
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (Include area code) (301) 394-3102

Contents

1. Introduction	1
2. Implementation of Blocks	2
2.1 Naming Conventions	2
2.2 Data Types	2
2.2.1 Block Signatures	3
2.2.2 Boost Pointers	4
2.3 Case Study: gr_block	4
2.3.1 Function: general_work()	6
2.3.2 Functions: forecast() and set_history()	7
2.3.3 Field: d_output_multiple	7
2.3.4 Field: d_relative_rate	8
3. Creation of SWIG Interfaces	8
3.1 Naming Conventions	8
3.1.1 Block Names	9
3.1.2 Boost Pointers	9
3.2 SWIG Interface File	11
4. Installation of Blocks	12
4.1 Directory	12
4.2 Preparing Makefile.am for Autotools	13
4.3 Installation	14

5. Usage of Blocks	15
5.1 Invoking from Python	15
5.2 Debugging	15
5.3 Simplifying the Build	16
6. Conclusion	16
A. The gr_block.h Script	17
B. The blockWizard.py Script	25
Distribution	35

List of Tables

1	Arguments of <code>general_work()</code>	6
2	Contents of <code>newBlock</code> directory in GNU Radio	13

INTENTIONALLY LEFT BLANK

1. Introduction

Software-defined radios (SDRs) provide researchers with a powerful and flexible wireless communications experimentation platform. GNU Radio is the most popular open-source software toolkit for deploying. Every SDR is comprised of software and hardware. In this document, we consider GNU Radio software coupled with Universal Software Radio Peripheral (USRP) hardware. In GNU Radio, C++ ***blocks*** perform specific signal processing tasks, while Python ***applications*** connect the blocks together to form a functional software radio. For example, a basic transmitter can be implemented by using Python to connect the following C++ blocks (which already exist in the GNU Radio software library) together: modulator, mixer, and amplifier.

Each block specifies its input and output requirements, both in number and type. For example, the `gr_add_cc` block adds two complex input streams and copies the results onto one complex output stream. Blocks are generally implemented in C++ for computational efficiency, but other possibilities exist (see below).

After writing a new block, a process is needed to expose these C++ blocks for use by Python scripts. GNU Radio uses the Simplified Wrapper and Interface Generator (SWIG), to generate the necessary components to make C++ blocks accessible from Python.

From the standpoint of Python applications, each block consumes its input stream(s), performs a specific task, and generates output stream(s). As long as the connections between blocks are compatible, there is no restriction to how many blocks can be chained together. A single output stream can connect to multiple input streams, but multiple outputs cannot connect to a single input due to ambiguity. A multiplexer can be used in such a situation by interleaving many inputs onto a single output.

In summary, the stages of block creation in GNU Radio are the following:

1. Implementation of blocks (C++), the
 (.h, .cc) files
2. Creation of SWIG interfaces between C++/Python, the
 (.i) file
3. Installation of blocks into a shared library
4. Usage of blocks in an application (Python), the
 (.py) file

In this report, we detail steps 1–4. This report is an updated and expanded presentation of the material found in <http://www.gnu.org/software/gnuradio/doc/howto-write-a-block.html>.

2. Implementation of Blocks

Before diving into block implementation, we first introduce the naming conventions of GNU Radio in section 2.1. Section 2.2 introduces the most commonly used data types, and section 2.3 steps through the essential elements of block creation by using the illustrative example of `gr_block`.

2.1 Naming Conventions

There are several strongly followed conventions in GNU Radio, and a familiarity with these expedites code writing and understanding.

- All words in identifiers are separated by an underscore, e.g., `gr_vector_int`.
- All types in the GNU Radio package are preceded by `gr`, e.g., `gr_float`.
- All class variables are preceded with `d_`, e.g., `d_min_streams`.
- Each classes is implemented in a separate file, e.g., class `gr_magic` is implemented in `gr_magic.cc` with the header file `gr_magic.h`.
- All signal processing blocks contain their input and output types in their suffixes, e.g., `gr_fft_vcc` requires complex inputs and complex outputs. The major types are float (*f*), complex (*c*), short (*s*), integer (*i*). Any type may be vectorized (*v*).

2.2 Data Types

GNU Radio type defines the most commonly used data types to a set of names. The main purpose of this is to create a common set of conventions for naming of data types. The list is as follows:

```
typedef std::complex<float>          gr_complex;
typedef std::complex<double>        gr_complexd;
typedef std::vector<int>             gr_vector_int;
typedef std::vector<float>           gr_vector_float;
```

```

typedef std::vector<double>          gr_vector_double;
typedef std::vector<void *>         gr_vector_void_star;
typedef std::vector<const void *>   gr_vector_const_void_star;
typedef short                       gr_int16;
typedef int                         gr_int32;
typedef unsigned short              gr_uint16;
typedef unsigned int                gr_uint32;

```

2.2.1 Block Signatures

A block signature is simply a specification of the data types that enter and exit a signal processing block. In list 1, we can examine `gr_io_signature.h` for more detail.

Listing 1. `gr_io_signature.h`

```

1 class gr_io_signature {
2     int          d_min_streams;
3     int          d_max_streams;
4     std::vector<int>    d_sizeof_stream_item;
5
6     gr_io_signature(int min_streams, int max_streams,
7                     const std::vector<int> &sizeof_stream_items);
8
9     friend gr_io_signature_sptr
10    gr_make_io_signaturev(int min_streams,
11                          int max_streams,
12                          const std::vector<int> &sizeof_stream_items);
13
14 public:
15
16     static const int IO_INFINITE = -1;
17
18     ~gr_io_signature ();
19
20     int min_streams () const { return d_min_streams; }
21     int max_streams () const { return d_max_streams; }
22     int sizeof_stream_item (int index) const;
23     std::vector<int> sizeof_stream_items() const;
24 };

```

It is important to realize that our block has two signatures, one for the input interface and one for the output interface. The header file makes it clear that, for a given interface, `gr_io_signature` defines the minimum and maximum number of streams flowing through that interface, as well as the number of bytes in a single element of the stream. Recall that Python is used to connect multiple signal processing blocks together. The main purpose of signatures is so Python can raise an error for improper connections.

The following are examples of improper connections:

- Too {many/few} {input/output} connections for a block
- Type mismatch, e.g., `gr_complex` output connected to `gr_int16` input

2.2.2 Boost Pointers

GNU Radio uses Boost smart pointers instead of regular C++ pointers. Boost is a high-quality software library with many extensions to the basic C++ language. For our purposes, Boost provides a smart implementation of C++ pointers that offers garbage collection, i.e., it deletes dynamically allocated objects when they are no longer needed. This simplifies our implementation efforts and improves block performance. There are actually many different types of smart pointers, but GNU radio uses just one of them, called a `shared_ptr`, which is used specifically when our dynamically allocated object has ownership shared by several pointers.

In order to declare a regular C++ pointer to an object of type `gr_io_signature`, we would use the following command:

```
gr_io_signature* ptr;
```

Whereas with Boost, we would use this command:

```
typedef boost::shared_ptr<gr_io_signature> gr_io_signature_sptr;  
gr_io_signature_sptr ptr;
```

to declare a Boost shared pointer.

As shown in the above code, GNU Radio uses the convention of type defining Boost smart pointers to an object of type `X` as `X_sptr`. This format makes it explicit to the user that `X_sptr` is a Boost smart pointer.

2.3 Case Study: `gr_block`

GNU Radio makes extensive use of the notion of “inheritance,” an object oriented (OO) programming technique. For us, this simply means that every signal processing block is a specialization of a general, high-level block, which GNU Radio calls `gr_block`. Our task is to fill in the details of `gr_block` (referred to in OO-speak as “deriving from the base

class”) to create our own custom block. It is prudent to begin our study of writing a new block by first examining `gr_block.h`.

The class `gr_block` is itself derived from the class `gr_basic_block.h`. We consider a few of the fields that are of particular interest to programmer and discuss the fields inherited from `gr_basic_block.h` and defined `gr_block.h` (lists 2 and 3). The entire `gr_block.h` file is shown in appendix A.

Listing 2. `gr_basic_block.h`

```
70     std::string          d_name;
71     gr_io_signature_sptr d_input_signature;
72     gr_io_signature_sptr d_output_signature;
73     long                d_unique_id;
```

Listing 3. `gr_block.h`

```
229 private:
230
231     int                d_output_multiple;
232     double             d_relative_rate;      // approx output_rate /
        input_rate
```

The fields `d_name` and `d_unique_id` are unique identifiers (text and numeral, respectively) for the block and can be used for debugging. The `d_output_multiple` and `d_relative_rate` fields inform the schedule of the block’s rate of data consumption and generation (see sections 2.3.3 and 2.3.4).

Note that `d_input_signature`, `d_output_signature`, and `d_detail` are all Boost smart pointers, the former pointing to `gr_io_signature` objects, the latter to a `gr_block_detail` object. The comments above highlight the purpose of the various fields; we explain in more detail in what follows.

As seen in list 4, `gr_block` has the following important functions.

Listing 4. `gr_block.h`

```
82     void set_history (unsigned history) { d_history = history; }
105     virtual void forecast (int noutput_items,
106                           gr_vector_int &ninput_items_required);
122     virtual int general_work (int noutput_items,
123                              gr_vector_int &ninput_items,
124                              gr_vector_const_void_star &input_items,
125                              gr_vector_void_star &output_items) = 0;
157     void consume (int which_input, int how_many_items);
```

In the remainder of this section, we detail each of these functions. It is useful to think of the process of writing a new block as a “two-way street” between our block and the GNU

Radio internals, collectively referred to herein as the ***scheduler***. The scheduler gives us data from the USRP, on which our block performs signal processing. In turn, our block tells the scheduler how much processing we've done and how much more input we need to produce more output, so the scheduler knows what data it no longer needs to store, how much buffer memory to allocate, when to schedule our block to execute next, etc. This, in turn, determines when the scheduler will invoke our block next and with how much input.

2.3.1 Function: `general_work()`

The `general_work()` function plays a central role in new block creation. It implements the process of converting the input stream(s) to the output stream(s). Table 1 explains the purpose of the arguments to this function.

Table 1. Arguments of `general_work()`.

Argument	Purpose
<code>noutput_items</code>	Number of output items to write on each output stream
<code>ninput_items</code>	Number of input items available on each input stream
<code>input_items</code>	Vector of pointers to elements of the input stream(s), i.e., element i of this vector points to the i^{th} input stream
<code>output_items</code>	Vector of pointers to elements of the output stream(s), i.e., element i of this vector points to the i^{th} output stream

Recall that we stated earlier that a signal processing block may have multiple input and/or output streams. So, `ninput_items` is vector whose i^{th} element is the number of available items on the i^{th} input stream. However, `noutput_items` is a scalar, not a vector, because GNU Radio implementation forces the number of output items to write on each output stream to be the same. The returned value of `general_work()` is the number of items actually written to each output stream, or -1 on end of file (EOF).

To create a block, we simply define how to create `output_items` from `input_items`, assuming that all parameters are provided to us. That is, ***we implement the signal processing algorithm*** in this method. The scheduler invokes the concrete implementation of `general_work` with the appropriate parameters. We do not have to explicitly invoke `general_work`; we only need to define it.

After we have defined `general_work` for our custom signal processing block, we need to invoke the `consume()` function to indicate to the scheduler how many items (`how_many_items`) have been processed on each (`which_input`) input stream. Recall that the scheduler is providing us all the appropriate parameters for us to write our own block; we need to provide feedback to the scheduler so it knows which elements have been used,

so it can mark appropriate memory for deletion or reuse, and update pointers to point to new data. This feedback of our signal processing progress is provided to the scheduler via the `consume` function.

2.3.2 Functions: `forecast()` and `set_history()`

The `forecast()` function is our way of telling the scheduler our estimate of the number of input elements that will be needed to create an output element. For example, a decimating filter of order 5 requires five inputs to produce one output. The key argument is `ninput_items_required`, which is a vector specifying the number of input items required on each input stream to produce `noutput_items` number of outputs on each output stream. In some cases, like the decimating filter of specified order, we may know this number exactly. In other cases, we may need to estimate it. When the scheduler determines it is ready to handle `noutput_items` more items on the output streams, it invokes the `forecast` function to determine whether or not we have enough input items to call `general_work`. For example, an interpolator will produce multiple outputs for a single input, while a decimator will produce a single output for multiple inputs. If we have a 10-to-1 decimator but only 9 inputs are available, the scheduler will not call `general_work` if the `forecast` function is correctly implemented.

There is an important distinction to make here. Another common requirement, such as for a moving average filter that averages the five most recent inputs to produce a single output, is the need to process multiple input samples to yield a single output sample. It may seem as if our `forecast` function should specify this. However, in this case, while the moving average filter uses five inputs to produce one output, it does not require five *new* inputs; it still only consumes a single *new* input to produce a single *new* output. So, our `forecast` function, in this case, would still call for a one-to-one relation of `noutput_items` to `ninput_items_required`. In this case, the fact that we need the five most recent inputs would be specified to GNU Radio via the `set_history(5)` function call.

2.3.3 Field: `d_output_multiple`

By now, we have seen that the GNU Radio scheduler is responsible for invoking `general_work` and `forecast`. The `forecast()` function allows us to signal to the scheduler to invoke our `general_work` function only when a sufficient number of input elements are in the input buffer. But we have not seen any such mechanism to control the number of outputs being produced. Recall the argument `noutput_items` in the `forecast` function. It is specified by the scheduler and contains how many output items to produce on each stream. While we cannot directly set this value (it is under the scheduler's control), there is a variable `d_output_multiple` that tells the scheduler that the value of

`noutput_items` must be an integer multiple of `d_output_multiple`. In other words, the scheduler only invokes `forecast()` and `general_work()` if `noutput_items` is an integer multiple of `d_output_multiple`. The default value of `d_output_multiple` is 1. Suppose, for instance, we are interested in generating output elements *only* in 64-element chunks. By setting `d_output_multiple` to 64, we can achieve this, but note that we may also get any multiple of 64, such as 128 or 192, instead.

The following functions allow us to set and get the value of `d_output_multiple`:

```
void    gr_block::set_output_multiple (int multiple);
int     output_multiple ();
```

2.3.4 Field: `d_relative_rate`

Recall our description of block creation as involving a "two-way communication" with the scheduler. The `d_relative_rate` field is the way we tell the scheduler the approximate ratio of output rate to input rate at which we expect our signal processing algorithm to operate. The key purpose of `d_relative_rate` is to allow the scheduler to optimize its use memory and timings of invocation of `general_work`. For many blocks, `d_relative_rate` is 1.0 (the default value), but decimators will have a value less than 1.0 and interpolators greater than 1.0.

The functions used to set and get the value of `d_relative_rate` are given below:

```
void    gr_block::set_relative_rate (double relative_rate);
double  relative_rate ();
```

3. Creation of SWIG Interfaces

In what follows, we strongly urge the reader to download the file `gr-howto-write-a-block-3.3.0.tar.gz` from <ftp.gnu.org/gnu/gnuradio/> and extract the archive. This archive contains sample code related to creating a new block, which we refer to.

3.1 Naming Conventions

Before getting into the details of block creation, let us start with a note about some important naming conventions.

3.1.1 Block Names

After we create our new block, the only way we can use it in GNU Radio is to create a Python script, which loads the package/module containing the block, and then connect our block into a GNU Radio flowgraph, as usual. This would involve Python code resembling the following:

```
from package_name import module_name
...
nb = module_name.block_name()
...
```

There is a key coupling between the module and block names that we invoke in Python, and the names used in coding blocks in C++. Namely, GNU Radio expects that all C++ source and header files are in the form `[module_name]_[block_name].h` and `[module_name]_[block_name].cc`. That is, if we decided to name our C++ class `newModule_newBlock`, then GNU Radio's build system would make our block available from Python in module "newModule" and with block name "newBlock". So while in theory there is no need for such a coupling of naming schemes, in practice, such a coupling does exist.

3.1.2 Boost Pointers

We have mentioned earlier that all pointers to GNU Radio block objects must use Boost shared pointers not "regular" C++ pointers. In other words, if we create a new C++ signal processing block called "`newModule_newBlock`", then GNU radio's internal implementation will not work if we use a pointer to `newBlock_newFunction` in our code. In other words, the command

```
newModule_newBlock* nb = new newModule_newBlock()
```

is not permitted. This is enforced by making all block constructors private and ensures that a regular C++ pointer can never point to a block object. But if the constructor is private, how do we create new instance of our block? After all, we need some sort of public interface for creating new block instances. The solution is to declare a "friend function," which acts as a surrogate constructor. This is achieved by first declaring a friend function of the class, so it has access to all private members, including the private constructor. This friend function invokes the private constructor and returns a smart pointer to it. Second, we invoke this friend function every time we want to construct a new object.

Suppose the name of our new signal processing block is `newModule_newBlock_cc`. Then, we would create a file `newModule_newBlock_cc.cc`, in which we would include the following function declaration:

```
typedef boost::shared_ptr<newModule_newBlock_cc> newModule_newBlock_cc_sptr;
friend newModule_newBlock_cc_sptr newModule_make_newBlock_cc()
```

Now, the function `newModule_newBlock_make_cc()` has access to private members of the class `newModule_newBlock_cc`. So from within this function, we call the private constructor of `newModule_newBlock_cc`, in order to create a new instance of our block. The final step is to cast the returned pointer's data type from a raw C++ pointer to a smart pointer

```
newModule_newBlock_cc_sptr newModule_make_newBlock_cc() () {
    return newModule_newBlock_cc_sptr (new newModule_newBlock_cc());
}
```

The private constructor (which we cannot invoke directly), on the other hand, would look something like this.

```
newModule_newBlock_cc ()    {
    gr_block ('newBlock_cc",
    gr_make_io_signature (1, 1, sizeof (gr_complex)),
    gr_make_io_signature (1, 1, sizeof (gr_complex))
    )
}
```

So to summarize, the private constructor is actually creating a new `gr_block` object. The “friend” constructor, the public interface to the private constructor, acts as a surrogate by wrapping the new object created by the private constructor into a Boost shared pointer. This convoluted procedure guarantees that all pointers to blocks are Boost smart pointers. The public interface to creating objects is not the object constructor `newModule_newBlock_cc`, but rather the “surrogate” constructor `newModule_newBlock_make_cc`.

Then, in our code, we must create a new block object using the code

```
newModule_newBlock_cc_sptr nb = newModule_make_newBlock_cc()
```

Here is an important point: if one’s block name is `newModule_newBlock_cc`, then the name of the shared pointer to this block **MUST** be `newModule_newBlock_cc_sptr`. Any other choice, such as `nb_nf_sptr`, would lead to the block not working properly. This has nothing to do with C++, since any valid name will work. Rather, when this C++ block is invoked from Python in a GNU Radio program, GNU Radio expects the shared pointer name to follow directly from the block name with an `_sptr` added on, or else it will complain that it cannot find the block.

Also, the surrogate constructor that creates a shared pointer to `newModule_newBlock_cc` *must* have signature

```
newModule_newBlock_cc_sptr newModule_make_newBlock_cc()
```

Note the presence of the word “make” between the `newModule` and `newBlock` words. Thus, consider the naming of shared pointers to block objects, as well as the friend functions (surrogate constructors) that create them, not as a convention *but as rule to be followed*.

3.2 SWIG Interface File

Once we have created our `.cc` and `.h` files, the next step is to create the SWIG (`.i`) file, so we can expose our new block to Python. SWIG is used to generate the necessary “glue,” as it is often called, to allow Python and C++ to “stick” together in a complete GNU Radio application. The purpose of the `.i` file is to tell SWIG how it should go about creating this glue.

A `.i` file is very similar to a `.h` file in C++ in that it declares various functions. However, the `.i` file only declares the functions that we want to access from Python. As a result, the `.i` file is typically quite short in length.

We illustrate an actual `.i` file in list 5, called `gr_multiply_const_ff.i`.

Listing 5. `gr_multiply_const_ff.i`

```

1 /*
2  * GR_SWIG_BLOCK_MAGIC is a function which allows us to invoke our block
3  * gr_multiply_const_ff_from Python as gr.multiply_const_cc()
4  * Its first argument, 'gr', will become the package prefix.
5  * Its second argument 'multiply_const_ff' will become the object name.
6  */
7
8 GR_SWIG_BLOCK_MAGIC(gr, multiply_const_ff)
```

```

9
10 /*
11  * gr_make_multiply_const_ff is the surrogate constructor
12  * i.e. the friend function of class gr_multiply_const_ff
13  */
14 gr_multiply_const_ff_sptr gr_make_multiply_const_ff (float k);
15
16
17 class gr_multiply_const_ff : public gr_sync_block
18 {
19     private:
20         gr_multiply_const_ff (float k); // the "true", private constructor
21
22     public:
23         float k () const { return d_k; }
24         void set_k (float k) { d_k = k; }
25 };

```

There are some important aspects to note from the above choices of names. First, the fact that we have invoked `GR_SWIG_BLOCK_MAGIC` with parameters “`gr`” and “`multiply_const_ff`” has direct relevance to how we invoke the block from Python. Practically, this means that in Python, when we seek to invoke our blocks, we would first use the command

```
import gr
```

When we wish to instantiate our block, we would use the Python command

```
block = gr.multiply_const_ff()
```

In summary, from within Python, `gr` is a package and `multiply_const_ff` is a function within this package. The way we have created the `.i` file specifies the particular names that Python ascribes to the package (`gr`) and function (`multiply_const_ff`).

4. Installation of Blocks

4.1 Directory

The next step involves placing various files in the correct locations to ensure a successful build. We assume that we have finished writing all the necessary files and now make our

new blocks accessible from Python. In this section, we outline the key steps needed to build new signal processing applications in GNU radio.

A sample block is available from the GNU Radio online package archive [?], where each block is version numbered as X.Y.Z to correspond to the analogous version of GNU Radio. Download and unpack this block to a directory of your choice, e.g., “newBlock”. The directory structure and significance of each folder is explained in table 2.

Table 2. Contents of newBlock directory in GNU Radio.

Directory	Contents
/home/user/newBlock	Top level Makefile, documentation
/home/user/newBlock/config	Files for GNU Autotools
/home/user/newBlock/src	Top level folder for C++ and Python files
/home/user/newBlock/src/lib	Folder for C++ source/header files

As we write our own blocks, keep in mind that all files (.h, .cc, and .i) for the new signal processing block should go in the newBlock/src/lib directory.

4.2 Preparing Makefile.am for Autotools

The final step before compilation is to edit the Makefile.am file (located in the previous example in the root directory, i.e., /home/user/newBlock). Makefile.am specifies which libraries to build, the source files that comprise those libraries, and the appropriate flags to use. This file contains relevant information to configure the build process that is to follow to correctly compile our code. Open this file and edit two sections. The first, shown below, identifies the name of SWIG’s .i file:

```
# Specify the .i file below
LOCAL_IFILES = newModule.i
```

The next tells SWIG which files to build and what to name them for use by Python:

```
BUILT_SOURCES = \
newModule.cc \
newModule.py
```

The next set of commands ensures that our new block’s Python code is installed in the proper location.

```

ourPython_PYTHON =
newModule.py
ourlib_LTLIBRARIES = _newModule.la

```

The next set of commands specify which source files are included in the shared library that SWIG exposes to Python:

```

_newModule_la_SOURCES =
newModule.cc
newModule_newBlock_cc.cc

```

The final set of commands specify key flags to ensure that our new signal processing block shared library compiled and linked correctly against SWIG and the C++ standard library:

```

_newModule_la_LDFLAGS = -module -avoid-version
_newModule_la_LIBADD =
-lgrswigrunpy
-lstdc++
newModule.cc newModule.py: newModule.i $(ALL_IFILES)
$(SWIG) $(SWIGCPPPYTHONARGS) -module newModule -o newModule.cc $<
grinclude_HEADERS =
newModule_newBlock_cc.h

```

4.3 Installation

After we finish coding our block, we need to install it. Fortunately, this process is made easy by the included makefile in the archive downloaded earlier. With the editing of the `Makefile.am` file as above, we are now ready to build our new block. Simply use the following commands:

```

./bootstrap
./configure --prefix=prefix
make
sudo make install
sudo touch install_path/package_name/__init__.py

```

Here, “prefix” is the root of our GNU radio installation (default is `/usr/local`). Also, “install_path” is the directory where our package is being installed (default is

prefix/lib/Python/Python-version/site-packages, where *Python-version* is the version of Python being used). Finally, "package_name" is the name of the Python package under which our block will be available. This would have been specified in `Makefile.am` by us during build time, so we just enter that name here. The creation of an `__init__.py` file is necessary since Python expects every directory containing a package to have this file.

If subsequently we make changes to our code, we can repeat the above steps but omit the bootstrap and configure steps.

5. Usage of Blocks

5.1 Invoking from Python

Our final step is to use our new block from Python as part of a GNU Radio flowgraph. This is easy using the following commands:.

```
from gnuradio import newModule
.....
block = newModule.newBlock_cc ()
....
```

5.2 Debugging

The challenge of debugging our new block is that we are not executing C++ code directly. Rather, our block, comprised of C++ code, is loaded dynamically into Python and executed "through" a Python process. Therefore, the most convenient debugging option involves inserting print statements through the block source code to monitor its status during execution. For those familiar with GDB (and often, many graphical debuggers use GDB under the covers), the following code can be used:

```
from gnuradio import newModule
import os #package providing blocking function
print 'My process id is (pid = %d)' % (os.getpid(),)
raw_input ('Please attach GDB to this process ID, then hit enter: ')
# now continue using our block
block = newModule.newBlock_cc();
```

The idea of this code is simply to discover the process ID of the Python process, which invokes our new block, and then in another terminal, have GDB attach to this process ID. Now, GDB can be used as usual (to set breakpoints, watch points, etc.) When we have configured GDB as we like, we can return to the terminal executing the Python process, and hit Enter to have it proceed.

5.3 Simplifying the Build

As we have mentioned previously, there are several caveats involved in the creation of a new signal processing block. Beyond just writing the C++ code, we must create a Makefile.am file and SWIG .i file, and be careful in the naming of various files and functions so as to adhere to GNU Radio's naming rules. These steps are a "one-time cost" associated with writing a new block. Then, we have to ensure all files are placed in the correct place, and then invoke a series of commands to compile, build, and deploy our application. These latter steps are a "recurring cost," which we must incur each time we go through the debug-build-test cycle. Overall, the process of building and deploying the block can be time-consuming and error-prone. To allow us to focus on creating new signal processing blocks in C++ and avoid dealing directly with the complexities of the build process and naming rules, we have created a script in Python. After the user has written a new block in C++, this script automates the rest of the process, ensuring that all naming rules are adhered to (and renaming accordingly when necessary) and all packages are properly built and usable from Python. The script is given in the appendix B.

6. Conclusion

In this report, we have provided the details of how to create a new signal processing block using GNU Radio. We have highlighted important naming conventions; surveyed the important functions to be overridden in `gr_block`, such as `general_work` and `forecast`; and illustrated the importance of Boost smart pointers. Finally, we have discussed how to compile a block, deploy it, and invoke it from Python.

A. The gr_block.h Script

```
1  /* -*- c++ -*- */
2  /*
3   * Copyright 2004,2007,2009,2010 Free Software Foundation, Inc.
4   *
5   * This file is part of GNU Radio
6   *
7   * GNU Radio is free software; you can redistribute it and/or modify
8   * it under the terms of the GNU General Public License as published by
9   * the Free Software Foundation; either version 3, or (at your option)
10  * any later version.
11  *
12  * GNU Radio is distributed in the hope that it will be useful,
13  * but WITHOUT ANY WARRANTY; without even the implied warranty of
14  * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the
15  * GNU General Public License for more details.
16  *
17  * You should have received a copy of the GNU General Public License
18  * along with GNU Radio; see the file COPYING. If not, write to
19  * the Free Software Foundation, Inc., 51 Franklin Street,
20  * Boston, MA 02110-1301, USA.
21  */
22
23 #ifndef INCLUDED_GR_BLOCK_H
24 #define INCLUDED_GR_BLOCK_H
25
26 #include <gr_basic_block.h>
27
28 /*!
29  * \brief The abstract base class for all 'terminal' processing blocks.
30  * \ingroup base_blk
31  *
32  * A signal processing flow is constructed by creating a tree of
33  * hierarchical blocks, which at any level may also contain terminal nodes
34  * that actually implement signal processing functions. This is the base
35  * class for all such leaf nodes.
36
37  * Blocks have a set of input streams and output streams. The
38  * input_signature and output_signature define the number of input
39  * streams and output streams respectively, and the type of the data
40  * items in each stream.
41  *
42  * Although blocks may consume data on each input stream at a
43  * different rate, all outputs streams must produce data at the same
44  * rate. That rate may be different from any of the input rates.
45  *
46  * User derived blocks override two methods, forecast and general_work,
47  * to implement their signal processing behavior. forecast is called
48  * by the system scheduler to determine how many items are required on
49  * each input stream in order to produce a given number of output
50  * items.
```

```

51  *
52  * general_work is called to perform the signal processing in the block.
53  * It reads the input items and writes the output items.
54  */
55
56  class gr_block : public gr_basic_block {
57
58  public:
59
60      //! Magic return values from general_work
61      enum {
62          WORK_CALLED_PRODUCE = -2,
63          WORK_DONE = -1
64      };
65
66      enum tag_propagation_policy_t {
67          TPP_DONT = 0,
68          TPP_ALL_TO_ALL = 1,
69          TPP_ONE_TO_ONE = 2
70      };
71
72      virtual ~gr_block ();
73
74      //!
75      * Assume block computes  $y_i = f(x_i, x_{i-1}, x_{i-2}, x_{i-3} \dots)$ 
76      * History is the number of  $x_i$ 's that are examined to produce one  $y_i$ .
77      * This comes in handy for FIR filters, where we use history to
78      * ensure that our input contains the appropriate "history" for the
79      * filter. History should be equal to the number of filter taps.
80      */
81      unsigned history () const { return d_history; }
82      void set_history (unsigned history) { d_history = history; }
83
84      //!
85      * \brief Return true if this block has a fixed input to output rate.
86      *
87      * If true, then fixed_rate_in_to_out and fixed_rate_out_to_in may be called
88      *
89      bool fixed_rate () const { return d_fixed_rate; }
90
91      // _____
92      //           override these to define your behavior
93      // _____
94
95      //!
96      * \brief Estimate input requirements given output request
97      *
98      * \param noutput_items           number of output items to produce
99      * \param ninput_items_required    number of input items required on each
100     * input stream
101
102     * Given a request to product \p noutput_items, estimate the number of
103     * data items required on each input stream. The estimate doesn't have

```

```

103  * to be exact, but should be close.
104  */
105  virtual void forecast (int noutput_items,
106                        gr_vector_int &ninput_items_required);
107
108  /*!
109  * \brief compute output items from input items
110  *
111  * \param noutput_items      number of output items to write on each output
112  *                           stream
113  * \param ninput_items       number of input items available on each input
114  *                           stream
115  * \param input_items        vector of pointers to the input items, one
116  *                           entry per input stream
117  * \param output_items       vector of pointers to the output items, one
118  *                           entry per output stream
119  *
120  * \returns number of items actually written to each output stream, or -1 on
121  *        EOF.
122  * It is OK to return a value less than noutput_items. -1 <= return value
123  * <= noutput_items
124  *
125  * general_work must call consume or consume_each to indicate how many items
126  * were consumed on each input stream.
127  */
128  virtual int general_work (int noutput_items,
129                           gr_vector_int &ninput_items,
130                           gr_vector_const_void_star &input_items,
131                           gr_vector_void_star &output_items) = 0;
132
133  /*!
134  * \brief Called to enable drivers, etc for i/o devices.
135  *
136  * This allows a block to enable an associated driver to begin
137  * transferring data just before we start to execute the scheduler.
138  * The end result is that this reduces latency in the pipeline when
139  * dealing with audio devices, usbps, etc.
140  */
141  virtual bool start();
142
143  /*!
144  * \brief Called to disable drivers, etc for i/o devices.
145  */
146  virtual bool stop();
147
148  // -----
149
150  /*!
151  * \brief Constrain the noutput_items argument passed to forecast and
152  *        general_work
153  *
154  * set_output_multiple causes the scheduler to ensure that the noutput_items
155  * argument passed to forecast and general_work will be an integer multiple
156  * of \param multiple The default value of output multiple is 1.

```

```

150     */
151 void set_output_multiple (int multiple);
152 int output_multiple () const { return d_output_multiple; }
153
154 /*!
155  * \brief Tell the scheduler \p how_many_items of input stream \p
156    which_input were consumed.
157 */
158 void consume (int which_input, int how_many_items);
159
160 /*!
161  * \brief Tell the scheduler \p how_many_items were consumed on each input
162    stream.
163 */
164 void consume_each (int how_many_items);
165
166 /*!
167  * \brief Tell the scheduler \p how_many_items were produced on output
168    stream \p which_output.
169 */
170 void produce (int which_output, int how_many_items);
171
172 /*!
173  * \brief Set the approximate output rate / input rate
174  *
175  * Provide a hint to the buffer allocator and scheduler.
176  * The default relative_rate is 1.0
177  *
178  * decimators have relative_rates < 1.0
179  * interpolators have relative_rates > 1.0
180 */
181 void set_relative_rate (double relative_rate);
182
183 /*!
184  * \brief return the approximate output rate / input rate
185 */
186 double relative_rate () const { return d_relative_rate; }
187
188 /*
189  * The following two methods provide special case info to the
190  * scheduler in the event that a block has a fixed input to output
191  * ratio. gr_sync_block, gr_sync_decimator and gr_sync_interpolator
192  * override these. If you're fixed rate, subclass one of those.
193 */
194 /*!
195  * \brief Given ninput samples, return number of output samples that will be
196    produced.
197  * N.B. this is only defined if fixed_rate returns true.
198  * Generally speaking, you don't need to override this.
199 */
200 virtual int fixed_rate_ninput_to_noutput(int ninput);

```

```

199
200  /*!
201   * \brief Given noutput samples, return number of input samples required to
202         produce noutput.
203   * N.B. this is only defined if fixed_rate returns true.
204   * Generally speaking, you don't need to override this.
205   */
206  virtual int fixed_rate_noutput_to_ninput(int noutput);
207
208  /*!
209   * \brief Return the number of items read on input stream which_input
210   */
211  uint64_t nitems_read(unsigned int which_input);
212
213  /*!
214   * \brief Return the number of items written on output stream which_output
215   */
216  uint64_t nitems_written(unsigned int which_output);
217
218  /*!
219   * \brief Asks for the policy used by the scheduler to moved tags downstream
220         .
221   */
222  tag_propagation_policy_t tag_propagation_policy();
223
224  /*!
225   * \brief Set the policy by the scheduler to determine how tags are moved
226         downstream.
227   */
228
229  void set_tag_propagation_policy(tag_propagation_policy_t p);
230
231  //
232
233
234
235
236
237
238
239
240
241
242
243
244
245

```

```

228
229 private:
230
231 int d_output_multiple;
232 double d_relative_rate; // approx output_rate /
233        input_rate
234 gr_block_detail_sptr d_detail; // implementation details
235 unsigned d_history;
236 bool d_fixed_rate;
237 tag_propagation_policy_t d_tag_propagation_policy; // policy for moving tags
238        downstream
239
240 protected:
241
242 gr_block (const std::string &name,
243           gr_io_signature_sptr input_signature,
244           gr_io_signature_sptr output_signature);
245
246 void set_fixed_rate(bool fixed_rate){ d_fixed_rate = fixed_rate; }

```

```

246
247 /*!
248 * |brief Adds a new tag onto the given output buffer.
249 *
250 * |param which_output an integer of which output stream to attach the tag
251 * |param abs_offset a uint64 number of the absolute item number
252 * |param abs_offset associated with the tag. Can get from nitems_written.
253 * |param key the tag key as a PMT symbol
254 * |param value any PMT holding any value for the given key
255 * |param srcid optional source ID specifier; defaults to PMT_F
256 */
257 void add_item_tag(unsigned int which_output,
258                 uint64_t abs_offset,
259                 const pmt::pmt_t &key,
260                 const pmt::pmt_t &value,
261                 const pmt::pmt_t &srcid=pmt::PMT_F);
262
263 /*!
264 * |brief Given a [start,end), returns a vector of all tags in the range.
265 *
266 * Range of counts is from start to end-1.
267 *
268 * Tags are tuples of:
269 * (item count, source id, key, value)
270 *
271 * |param v a vector reference to return tags into
272 * |param which_input an integer of which input stream to pull from
273 * |param abs_start a uint64 count of the start of the range of interest
274 * |param abs_end a uint64 count of the end of the range of interest
275 */
276 void get_tags_in_range(std::vector<pmt::pmt_t> &v,
277                       unsigned int which_input,
278                       uint64_t abs_start,
279                       uint64_t abs_end);
280
281 /*!
282 * |brief Given a [start,end), returns a vector of all tags in the range
283 * with a given key.
284 *
285 * Range of counts is from start to end-1.
286 *
287 * Tags are tuples of:
288 * (item count, source id, key, value)
289 *
290 * |param v a vector reference to return tags into
291 * |param which_input an integer of which input stream to pull from
292 * |param abs_start a uint64 count of the start of the range of interest
293 * |param abs_end a uint64 count of the end of the range of interest
294 * |param key a PMT symbol key to filter only tags of this key
295 */
296 void get_tags_in_range(std::vector<pmt::pmt_t> &v,
297                       unsigned int which_input,
298                       uint64_t abs_start,
299                       uint64_t abs_end,

```

```

300         const pmt::pmt_t &key);
301
302     // These are really only for internal use, but leaving them public avoids
303     // having to work up an ever-varying list of friends
304
305     public:
306         gr_block_detail_sptr detail () const { return d_detail; }
307         void set_detail (gr_block_detail_sptr detail) { d_detail = detail; }
308     };
309
310     typedef std::vector<gr_block_sptr> gr_block_vector_t;
311     typedef std::vector<gr_block_sptr>::iterator gr_block_viter_t;
312
313     inline gr_block_sptr cast_to_block_sptr (gr_basic_block_sptr p)
314     {
315         return boost::dynamic_pointer_cast<gr_block, gr_basic_block>(p);
316     }
317
318
319     std::ostream&
320     operator << (std::ostream& os, const gr_block *m);
321
322 #endif /* INCLUDED_GR_BLOCK_H */

```

INTENTIONALLY LEFT BLANK

B. The blockWizard.py Script

```
1  #!/usr/bin/env python
2
3  #This code simplifies the process of writing new blocks. Simply download the
   archive "gr-howto-write-a-block-3.3.0.tar.gz" from
4  #ftp://ftp.gnu.org/gnu/gnuradio/gr-howto-write-a-block-3.3.0.tar.gz , extract
   it to a directory "topdir",
5  #and create your custom block in C++ , placing it in topdir/src/lib . Then
   run this script.
6  #The user only needs to implement the block, for example
7  #particularly "general_work" and "forecast" functions. It handles installation
   of shared library,
8  #and ensures various naming "conventions" (really rigid rules), such as name
   of surrogate friend constructor,
9  #expected by the build system are followed. It handles the proper creation of
   the swig file.
10
11 import os
12 import re
13 import sys
14
15 print "\n!!!"
16 print "This wizard helps build (multiple) signal processing blocks, and places
   them in a single module of a single package"
17 print "You only really need to use this the first time you create a new block;
   then, for subsequent code changes to that same block, just use make and
   sudo make install"
18 print "This script will delete old autotools related files from this directory
   and generate new ones; if you have any concerns, backup before
   proceeding"
19 print "!!!"
20 raw_input("Press enter to continue, Ctrl-C to abort:")
21
22
23 print ("\nCleaning files from aborted previous runs ... ")
24 os.system("make clean")
25 os.system("rm -rf src/lib/Makefile.am")
26 os.system("rm -rf src/lib/Makefile")
27 os.system("rm -rf src/lib/Makefile.in")
28 os.system("rm -rf src/lib/.deps")
29 os.system("rm -rf src/lib/*.i")
30 os.system("rm -rf src/lib/Makefile.swig.gen")
31
32 src_headers = list()
33 src_source = list()
34
35 class_inheritance = dict()
36 friend_constructor = dict()
37 constructor = dict() #maps header files to the signature of their constructors
38 destructor = dict() #maps header files to the signature of their destructors
39
```

```

40
41 prefix = raw_input( '\n\nSpecify _prefix:_ [ prefix]/lib/python[ version]/site-
    packages_( default_=_/usr/local):_')
42 if len(prefix) == 0:
43     prefix="/usr/local"
44
45
46 version = raw_input( '\n\nSpecify _python_version:_ ' + prefix + '/lib/python[
    version]/site-packages_( default_=_2.6):_')
47 if len(version) == 0:
48     version="2.6"
49
50 install_path = prefix + "/lib/python" + version + "/site-packages"
51 install_path_alt = prefix + "/lib/python" + version + "/dist-packages" #
    installation may occur to here instead
52
53 print( '\n\nThe _python_command_to_import_this_block_will_be:_from_[ package_name]_
    import_[ module_name]_')
54 package_name = raw_input( 'Enter _desired_package_name_( default=testpackage):_')
55 if len(package_name) == 0:
56     package_name="testpackage"
57
58 module_name = raw_input( 'Enter _desired_module_name_( default=testmodule):_')
59 if len(module_name) == 0:
60     module_name="testmodule"
61
62 all_files=os.listdir( os.getcwd() + "/src/lib")
63
64 #create lists of the .h files and the .cc files
65 for filename in all_files:
66     #header_pattern = re.compile( '[\w]+.h')
67     #suffix_pattern = re.compile( '[\w]+.cc')
68
69     if ".h" in filename:
70         src_headers.append(filename)
71
72     if ".cc" in filename:
73         src_source.append(filename)
74
75
76
77 print( '\n\nThe _python_command_to_create_this_block_will_be:_object_=_ ' +
    module_name + '._[ block_name]_()')
78 i = 0
79 block_names={} #dictionary mapping header file to block name
80 for filename in src_headers:
81     i = i + 1
82     block_name = raw_input( 'Enter _desired_block_name_corresponding_to_block_
        implemented_in_' + filename[:-2] + '__( default=test_block' + str(i) + '
        ,_0_for_none):_')
83     if len(block_name) == 0:
84         block_name="test_block" + str(i)
85     if block_name == 0:
86         block_name=""

```

```

87     block_names[filename] = block_name
88
89
90
91 #figure out which classes inherit from which blocks (e.g. from gr_block or
92 gr_sync_block (allow for helper classes which do not inherit at all)
93 class_dec_pattern = re.compile('[\s]*class[\s\w]+:')
94 for filename in src_headers:
95     f = open(os.getcwd() + "/src/lib/" + filename, 'r')
96     for line in f:
97         if class_dec_pattern.match(line):
98             m = re.search('[\s]+[\w]+$' , line) #find the name of the class
99             that is inherited
100             if m:
101                 class_inheritance[filename] = m.group().strip()
102             else:
103                 class_inheritance[filename] = ""
104         f.close()
105
106 #figure out the signature of the constructor from each .h file
107 # key idea is to look for string of the form "filename(" (where
108 filename is without the .h)
109 for filename in src_headers:
110     constructor_string=""
111     constructor_name=filename[:-2] #everything but the .h
112     multi_line=0
113
114     f = open(os.getcwd() + "/src/lib/" + filename, 'r')
115
116     for line in f:
117         if ((constructor_name + "(" in line) or ((constructor_name + "_(" in
118             line): #this line contains a constructor declaration
119             constructor_string=line
120             if ("public" in previous_line) or ("private" in previous_line) or
121             ("protected" in previous_line):
122                 constructor_string = previous_line + constructor_string
123                 if ";" in line: #the constructor declaration is all on one line
124                     multi_line=0 #does the constructor declaration span multiple
125                     lines?
126                     break
127                 else:
128                     multi_line=1
129                     continue
130
131         if multi_line == 1: #the constructor declaration is over multiple
132             lines
133             constructor_string = constructor_string + line
134             if ";" in line: #look for end of this constructor declaration, i.e
135                 a semicolon
136                 break

```

```

133         previous_line = line #save the previous line for future use in case we
134             need to look back
135     constructor[filename] = constructor_string #there is one constructor per
136         class obviously
137 f.close()
138
139
140
141
142
143
144
145
146
147 #figure out the signature of the destructor from each .h file
148 # key idea is to look for string of the form          "~filename" (where
149     filename is without the .h)
149 for filename in src_headers:
150
151     destructor_string=""
152     destructor_name=filename[:-2] #everything but the .h
153     multi_line=0
154
155     f = open(os.getcwd() + "/src/lib/" + filename, 'r')
156
157     for line in f:
158         if ("~" + destructor_name) in line: #this line contains a destructor
159             declaration
160             destructor_string=line
161             if ("public" in previous_line) or ("private" in previous_line) or
162                 ("protected" in previous_line):
163                 destructor_string = previous_line + destructor_string
164                 if ";" in line: #the destructor declaration is all on one line
165                     multi_line=0 #does the destructor declaration span multiple
166                         lines?
167                     break
168             else:
169                 multi_line=1
170                 continue
171
172         if multi_line == 1: #the destructor declaration is over multiple lines
173             destructor_string = destructor_string + line
174             if ";" in line: #look for end of this destructor declaration, i.e
175                 a semicolon
176                 break
177
178     previous_line = line #save the previous line for future use in case we
179         need to look back
180
181     destructor[filename] = destructor_string #there is one constructor per
182         class obviously

```

```

178 f.close()
179
180
181
182
183
184
185
186 #figure out the friend function (from .h file) acting as the public interface
    for object construction (allow for helper classes that do not have this)
187 for filename in src_headers:
188
189
190     friend=""
191     target="+_)(*%#@#NNKSJAHFIUWEROIWEALSKJFD"
192     multi_line=0
193
194     f = open(os.getcwd() + "/src/lib/" + filename, 'r')
195
196     for line in f:
197         if "boost::shared_ptr" in line: #this line contains a typedef, we want
            to know the name of the alias so we can find its declaration
198             target = line.strip().split("_")[1] #get the last word, then
                drop the semicolon of that last word
199             continue
200
201         if target in line:
202             #friends.append(line.strip())
203             friend=line
204             if ";" in line: #the friend declaration is all on one line
205                 multi_line=0 #does the friend declaration span multiple lines?
                    no
206                 break
207             else:
208                 multi_line=1
209                 continue
210
211         if multi_line == 1: #the friend declaration is over multiple lines
            #friends.append(line.strip())
212             friend = friend + line
213             if ";" in line: #look for end of this friend declaration, i.e a
                semicolon
214                 break
215
216
217     friend_constructor[filename] = friend
218
219 f.close()
220
221
222
223 print
224 print "
    *****
    "

```

```

225 print "Block will be imported in python as: " + package_name
    + " import " + module_name
226
227 for value in block_names.values():
228     if len(value) > 1:
229         print "New objects in python will be made as: " +
            module_name + "." + value + "()"
230
231
232 print "Detected block header files are: ", src_headers
233 print "Detected block source files are: ", src_source
234 print "Block classes inherit gnuradio base classes as: ", class_inheritance
235 print "Class constructors are: ", constructor
236 print "Class destructors are: ", destructor
237 print "Friend public constructors are: ", friend_constructor
238 print "Install path of this package is: ", install_path
239 print "
    *****
    "
240
241 raw_input( '\nPress enter to continue , or Ctrl_C to abort')
242
243
244
245
246 #create .i file
247 swig_i_file = open(os.getcwd() + "/src/lib/" + module_name + ".i", 'w')
248 swig_i_file.write( '/*-*-c++-*-*/')
249 swig_i_file.write( '\n#include "gnuradio.i"')
250 swig_i_file.write( '\n%{')
251 for filename in src_headers:
252     swig_i_file.write( '\n#include "' + filename + '"')
253 swig_i_file.write( '\n%}')
254
255 for filename in src_headers:
256     if (block_names[filename] != '0'): #check that this really corresponds to
        a block implementation and not helper files
257         swig_i_file.write( '\n\nGR_SWIG_BLOCK_MAGIC(' + module_name + ', ' +
            block_names[filename] + ');')
258         swig_i_file.write( '\n\n' + friend_constructor[filename])
259
260 #write the class definition and constructors/destructors in it
261 swig_i_file.write( '\n\n' + 'class ' + filename[:-2] + ': public ' +
    class_inheritance[filename])
262 swig_i_file.write( '\n{')
263 swig_i_file.write( '\n\n' + constructor[filename])
264 swig_i_file.write( '\n\n' + destructor[filename])
265 swig_i_file.write( '\n};')
266
267 swig_i_file.close()
268
269
270 #create Makefile.am file in /src/lib
271 Makefile_am_file = open(os.getcwd() + "/src/lib/Makefile.am", 'w')

```

```

272
273 Makefile_am_file.write('include_$(top_srcdir)/Makefile.common')
274 Makefile_am_file.write('\n\ngninclude_HEADERS_=\')
275 i = 0
276 for filename in src_headers:
277     i = i + 1
278     Makefile_am_file.write('\n\t' + filename)
279     if (i < len(src_headers)):
280         Makefile_am_file.write('\n\t')
281
282 Makefile_am_file.write('\n\n\nTOP_SWIG_IFILES_=\')
283 Makefile_am_file.write('\n\t' + module_name + '.i')
284
285 Makefile_am_file.write('\n\n' + module_name + '_pythondir_category_=\')
286 Makefile_am_file.write('\n\t' + package_name)
287
288 Makefile_am_file.write('\n\n' + module_name + '_la_swig_sources_=\')
289 i = 0
290 for filename in src_source:
291     i = i + 1
292     Makefile_am_file.write('\n\t' + filename)
293     if (i < len(src_source)):
294         Makefile_am_file.write('\n\t')
295
296 Makefile_am_file.write('\n\n\ninclude_$(top_srcdir)/Makefile.swig')
297 Makefile_am_file.write('\n\n\nBUILT_SOURCES_=$(swig_built_sources)')
298 Makefile_am_file.write('\n\n\nno_dist_files_=$(swig_built_sources)')
299
300 Makefile_am_file.close()
301
302 #create Makefile.am in /src/python
303 Makefile_am_file = open(os.getcwd() + "/src/python/Makefile.am", 'w')
304 Makefile_am_file.write('include_$(top_srcdir)/Makefile.common')
305 Makefile_am_file.close()
306
307
308 #create Makefile.swig.gen
309 os.system("cp src/lib/Makefile.swig.gen.TEMPLATE src/lib/Makefile.swig.gen")
310 module_command = "sed -i s/testmodule/" + module_name + "/gI src/lib/Makefile.
    swig.gen"
311 package_command = "sed -i s/gnuradio/" + package_name + "/gI src/lib/Makefile.
    swig.gen"
312 os.system(module_command)
313 os.system(package_command)
314
315
316 #The build system expects source files to be of the form [module_name]_[
    block_name].h or [module_name]_[block_name].cc
317 #This is based off a gnu radio convention. If our files are NOT in this form,
    copy them over into that form
318 #It also expects the friend public constructor to be of the form [module_name]
    _make_[block_name]
319 #create source files that are named according to gnu radio convention, i.e.
    modulename_blockname.h and .cc (in case they don't exist) so that make is

```

```

happy
320 conforming_source_files = list() #list of source files conforming to proper
    gnu radio naming convention
321 swig_i_file = "src/lib/" + module_name + ".i"
322 Makefile_am_file = "src/lib/Makefile.am"
323
324 for f in block_names.keys(): #loop over all source files
325     make_function=""
326     ideal_make_function=""
327
328     filename = "src/lib/" + f
329     ideal_name = "src/lib/" + module_name + "_" + block_names[f]
330
331     if (not os.path.isfile(ideal_name + ".h")): #the conforming, conventional
        name does not exist; create it
332         raw_input("\nSource_names do not conform to GNU radio convention!
            Press enter to continue with auto-renaming ....\n")
333         tmp_file = ideal_name + ".h"
334         cmd = "cp" + filename[:-2] + ".h" + tmp_file
335         os.system(cmd)
336         conforming_source_files.append(tmp_file)
337         rename_command = "sed -i s/" + f[:-2] + "/" + module_name + "_" +
            block_names[f] + "/gI" + tmp_file
338         os.system(rename_command)
339
340     #correct the friend public interface name to conform to gnu radio
341     if len(friend_constructor[f]) > 0: #this file has a friend
        constructor
342         tokens=friend_constructor[f].split() #splits on any whitespace,
            even consecutive whitespaces which are treated as a single
            whitespace, which we want
343         make_function=tokens[1].strip() #the name of the public interface
            friend constructor
344         if "();" in make_function:
345             make_function=make_function[:-3]
346         elif "()" in make_function:
347             make_function=make_function[:-2]
348         ideal_make_function = module_name + "_make_" + block_names[f]
349         rename_command = "sed -i s/" + make_function + "/" +
            ideal_make_function + "/gI" + tmp_file
350         os.system(rename_command)
351
352         tmp_file = ideal_name + ".cc"
353         cmd = "cp" + filename[:-2] + ".cc" + tmp_file
354         os.system(cmd)
355         conforming_source_files.append(tmp_file)
356         rename_command = "sed -i s/" + f[:-2] + "/" + module_name + "_" +
            block_names[f] + "/gI" + tmp_file
357         os.system(rename_command)
358         rename_command = "sed -i s/" + make_function + "/" +
            ideal_make_function + "/gI" + tmp_file
359         os.system(rename_command)
360
361     #the swig .i file needs to be updated to reflect this name change as

```

```

362         well
363         rename_command = "sed -i s/" + f[: -2] + "/" + module_name + "_" +
364             block_names[f] + "/gI" + swig_i_file
365         os.system(rename_command)
366         rename_command = "sed -i s/" + make_function + "/" +
367             ideal_make_function + "/gI" + swig_i_file
368         os.system(rename_command)
369
370         #the Makefile.am file needs to be updated to reflect this name change
371         as well
372         rename_command = "sed -i s/" + f[: -2] + "/" + module_name + "_" +
373             block_names[f] + "/gI" + Makefile_am_file
374         os.system(rename_command)
375         rename_command = "sed -i s/" + make_function + "/" +
376             ideal_make_function + "/gI" + Makefile_am_file
377         os.system(rename_command)
378
379         raw_input('Requisite files for autotools have been created. Press enter to
380             continue with bootstrap, configure, make, make install; or Ctrl-C to abort
381             ')
382
383         print ("\n\nRunning bootstrap.....")
384         os.system("./bootstrap")
385
386         print ("\n\nRunning configure.....")
387         os.system("./configure --prefix=" + prefix)
388
389         print ("\n\nRunning make.....")
390         os.system("make")
391
392         print ("\n\nRunning sudo make install.....")
393         os.system("sudo make install")
394
395         print ("\n\nMaking" + package_name + "a proper python package.....")
396         if os.path.isdir(install_path + "/" + package_name):
397             os.system("sudo touch" + install_path + "/" + package_name + "/__init__.
398                 py")
399         else:
400             os.system("sudo touch" + install_path_alt + "/" + package_name + "/"
401                 + "__init__.py")
402
403         cleanup = raw_input("Do you want to erase all temporary makefiles and swig
404             files? (default=yes)")
405         if ("y" in cleanup) or ("Y" in cleanup) or (len(cleanup) == 0):
406             print ("\n\nDoing final cleanup.....")
407             os.system("make clean")

```

```

405 os.system("rm-rf src/lib/Makefile")
406 os.system("rm-rf src/lib/Makefile.am")
407 os.system("rm-rf src/lib/Makefile.in")
408 os.system("rm-rf src/lib/.deps")
409 os.system("rm-rf src/lib/*.i")
410 os.system("rm-rf src/lib/Makefile.swig.gen")
411
412 if len(conforming_source_files) > 0:
413     cleanup = raw_input("Do you want to erase all renamed source files? (
         default=yes)")
414     if ("y" in cleanup) or ("Y" in cleanup) or (len(cleanup) == 0):
415         #remove re-named source files, they are no longer needed
416         for f in conforming_source_files:
417             cmd = "rm-rf " + f
418             os.system(cmd)
419
420
421
422 print ("\n\nYour block is ready to use")

```

NO. OF COPIES	ORGANIZATION
1 ELEC	ADMNSTR DEFNS TECHL INFO CTR ATTN DTIC OCP 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218
1	US ARMY RSRCH DEV AND ENGRG CMND ARMAMENT RSRCH DEV & ENGRG CTR ARMAMENT ENGRG & TECHN LGY CTR ATTN AMSRD AAR AEF T J MATTS BLDG 305 ABERDEEN PROVING GROUND MD 21005-5001
1	US ARMY INFO SYS ENGRG CMND ATTN AMSEL IE TD A RIVERA FT HUACHUCA AZ 85613-5300
1	COMMANDER US ARMY RDECOM ATTN AMSRD AMR W C MCCORKLE 5400 FOWLER RD REDSTONE ARSENAL AL 35898-5000
1	US GOVERNMENT PRINT OFF DEPOSITORY RECEIVING SECTION ATTN MAIL STOP IDAD J TATE 732 NORTH CAPITOL ST NW WASHINGTON DC 20402
8	US ARMY RSRCH LAB ATTN IMNE ALC HRR MAIL & RECORDS MGMT ATTN RDRL CI J PELLEGRINO ATTN RDRL CIN A KOTT ATTN RDRL CIN T B RIVERA ATTN RDRL CIN T G VERMA ATTN RDRL CIN T P YU ATTN RDRL CIO LL TECHL LIB ATTN RDRL CIO MT TECHL PUB ADELPHI MD 20783-1197

INTENTIONALLY LEFT BLANK.